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Engineering Manufacturing Readiness Levels (EMRLs) Fundamentals, Criteria and Metrics

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Purpose

Information brief on the fundamentals, criteria and metrics for Engineering Manufacturing Readiness Levels (EMRLs)

Need for EMRLs

- **Successful products require the capture of design and manufacturing knowledge early in product development**
- **DoD acquisition policy does not require the capture of design and manufacturing knowledge or sufficiently specific criteria/metrics to enter System Integration and Demonstration (milestone B) and Production (milestone C) phases**
- **EMRLs provide the framework with specific criteria and metrics to capture the design and manufacturing knowledge for product development, demonstration and production**

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EMRL DEFINITION

EMRL 1 - System, component or item validation in initial relevant engineering application/bread board, brass board development. Product Design/Definition phase. Technologies must have matured to at least TRL 4 or 5. Exit Criteria CKP1 (Milestone B) indicates readiness for Product Integration Phase. This is the lowest level of production readiness. Technologies must have matured to at least TRL 4 or 5. At this point all requirements have not been finalized and there are significant engineering/design changes. Component physical and functional interfaces have not been completely defined. Manufacturing processes and procedures and inspection and test equipment are in development. Overall quality and reliability levels and key characteristics initially identified, but not established. Design to Cost goals identified.

EMRL 2 - System, component or item in prototype demonstration beyond bread board, brass board development. Product Integration Phase. Technologies must have matured to at least TRL 6 or 7. Exit Criteria CKP2 (includes successful completion of Product CDR) indicates readiness for Product Demonstration Phase.
Technologies must have matured to at least TRL 6-7. Systems engineering requirements are validated and defined. However, there are still many systems engineering/design changes and physical and functional interfaces are not yet fully defined. Materials are initially demonstrated in production and manufacturing processes and procedures are initially demonstrated. Investments required for machines and tooling are identified. Inspection and test equipment tested in a manufacturing environment. Quality and reliability levels and key characteristics initially identified. Design to Cost goals validated.

EMRL 3 - System, component or item in advanced development. Product Demonstration Phase. Technologies must have matured to at least TRL 8. Exit Criteria CKP3 (Milestone C) indicates readiness for low rate initial production. Technologies must have matured to at least TRL 8. At this point engineering/design changes have decreased significantly. Physical and functional interfaces have been clearly defined. All materials are in production and readily available. Manufacturing processes and procedures should be well understood, under control and ready for low rate initial production. Machines and tooling should have completed demonstration in a production environment. All quality and reliability requirements and key characteristics should be identified though not necessarily fully capable or in control. Tooling, STE and facilities meet LRIP requirements. Design to Cost goals met for LRIP.

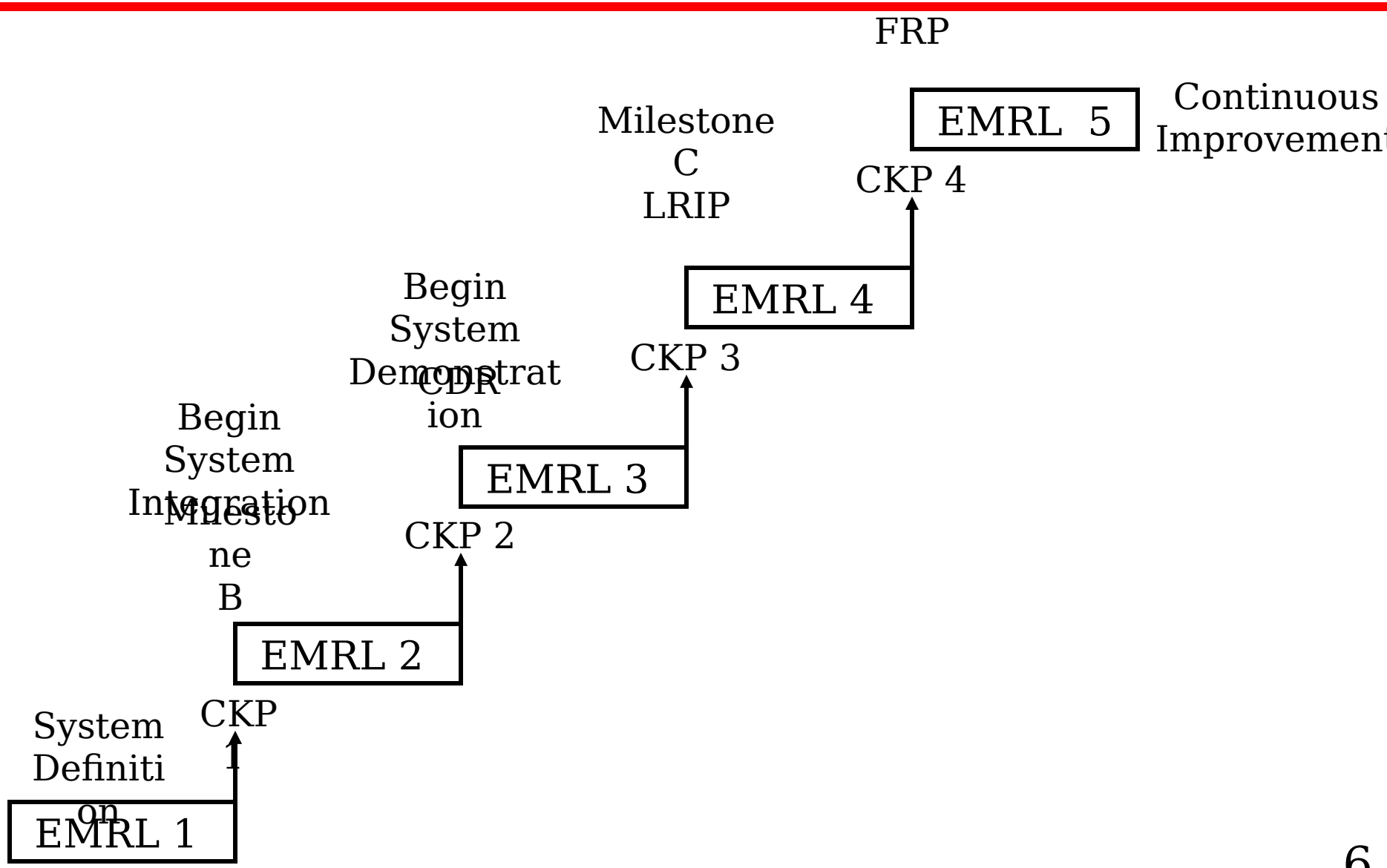
EMRL 4 - Similar system, component or item previously produced or in production. Or, the system, component or item is in low rate initial production. Technologies must have matured to at least TRL 9. Exit Criteria CKP4 indicates readiness for full rate production. Technologies must have matured to at least TRL 9. All systems engineering/design requirements should be met and there should be only minimal systems engineering/design changes. Materials are fully characterized, in production and readily available. Manufacturing processes and procedures are established and controlled in production to three-sigma or some other appropriate quality level. All key characteristics are controlled to three-sigma or some other appropriate quality level in production. Tooling, STE and facilities meet FRP requirements. Design to Cost goals met for FRP.

EMRL 5 - System, component or item is in full rate production with continuous product/process improvement. This is the highest level of production readiness. There are essentially no engineering/design changes. All materials, manufacturing processes and procedures, inspection and test equipment, quality, reliability and key characteristics controlled in production to six-sigma or some other appropriate quality level in production. Continuous improvement

EMRLs and Capability Knowledge Points (CKPs)

- **EMRLs describe the basic level of knowledge and capability required for a given acquisition phase. Product manager continuously assesses progress against EMRL criteria**
- **CKPs are the exit criteria and metrics for each EMRL and indicate the degree of product maturity or readiness for entry into the next acquisition phase**

EMRLs and Acquisition Milestones



EMRL Metrics and Exit Criteria

System EMRL 1 Capability Knowledge Point 1 Milestone B	System EMRL 2 Capability Knowledge Point 2 System CDR	System EMRL 3 Capability Knowledge Point 3 Milestone C
• System TRL=4 or 5-9 •All system engineering/design requirements defined; 50% validated • Component physical and functional interfaces 50% defined at system level • Materials, machines and tooling demonstrated in a lab environment (system) • Manufacturing process and system level integration demonstrated •Quality and reliability levels identified and established for 50% of the system • Key characteristics identified for 50% of the system •PDR complete at system level • 90% of items and components for system/major Subsystem are proven designs or in production; EMRL 2-3 (hardware and software) and CDR complete •75% of major subsystems (those representing 80% of cost) meet requirements of CKP2 and complete CDR •Failure modes and effects analysis required for all levels	• System TRL=6 or 7-9 •All system engineering/design requirements defined; 90% validated • Component physical and functional interfaces 90% defined at system level • System level manufacturing process and Inte-gration established in a production environment • Materials, machines and tooling established in a production environment • Quality and reliability levels identified and established for 90% of the system • Key characteristics identified for 90% of the system • CDR complete at system level • All items and components in production and meet cost, quality and reliability targets • 75% of major subsystems representing 80% of cost meet the requirements of CKP3 and are ready for or in LRIP • Failure modes and effects analysis complete on all items and components, 75% complete at system level • Funding identified to proceed to CKP3	• System TRL=8-9 •All system engineering/design requirements defined and validated • Minimal engineering changes • All Component physical and functional interfaces defined and validated at system level • All manufacturing processes are understood and in control for LRIP • All Machines, tooling and test equipment purchased and ready for LRIP in a production environment • All Quality and reliability levels established and verified • All Key characteristics identified and verified • Follow up issues from CDR cleared • All items and components (hardware and software) are ready for on-time delivery (or delivered) • All items and components meet cost, quality and reliability targets • Failure modes and effects analysis complete complete at system level • Reliability growth plan in place at all levels • Funding identified for reliability

Metrics Reporting and Roll Up

- **Color coded success/failure for each question/requirement**
  - Meet 100% of the requirement (Green)
  - Requirement not met, requirement will be met within the current schedule and cost (Yellow)
  - Requirement not met, meeting requirement will impact current schedule or cost (Red)
- **Metrics are rolled up from lower level of WBS to higher level(s)**

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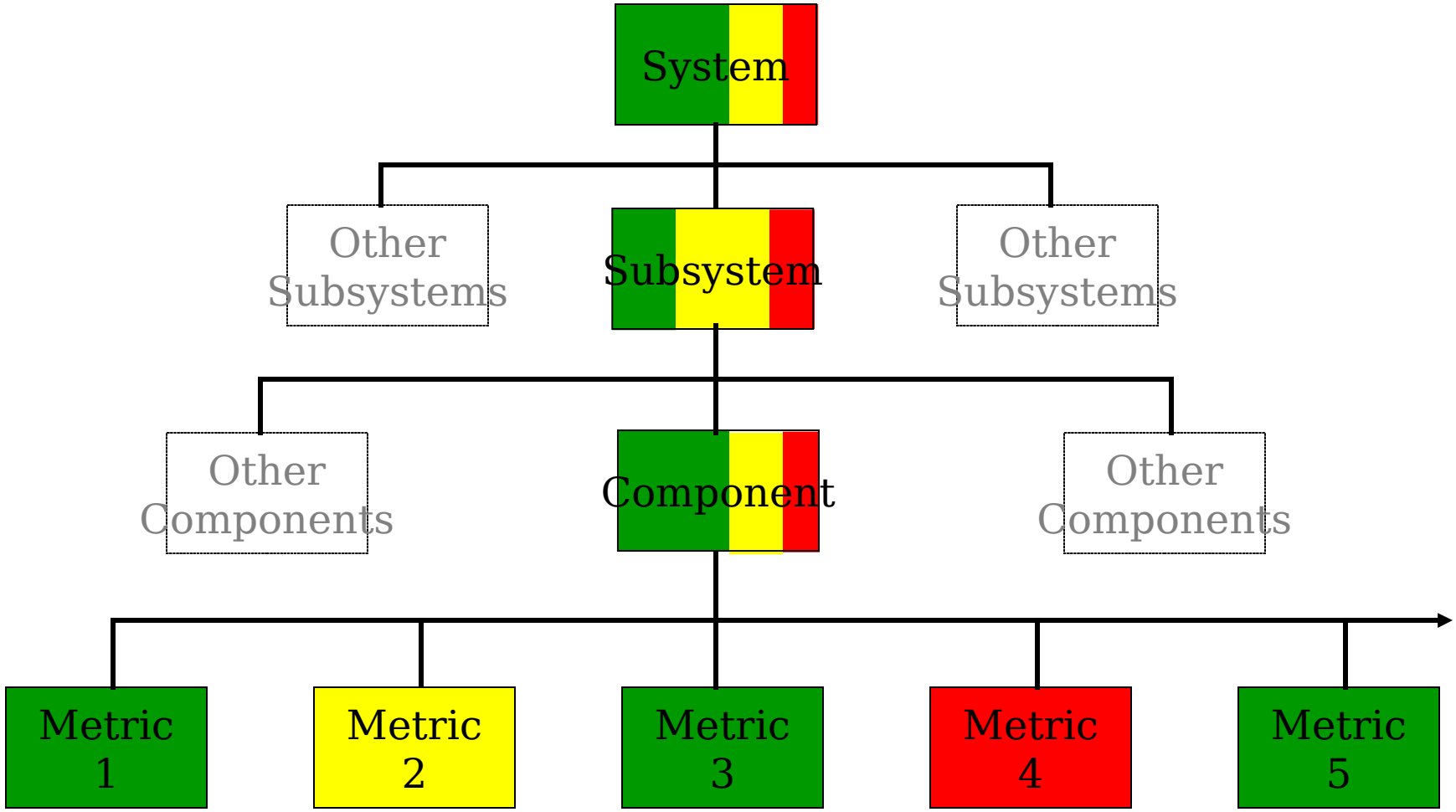
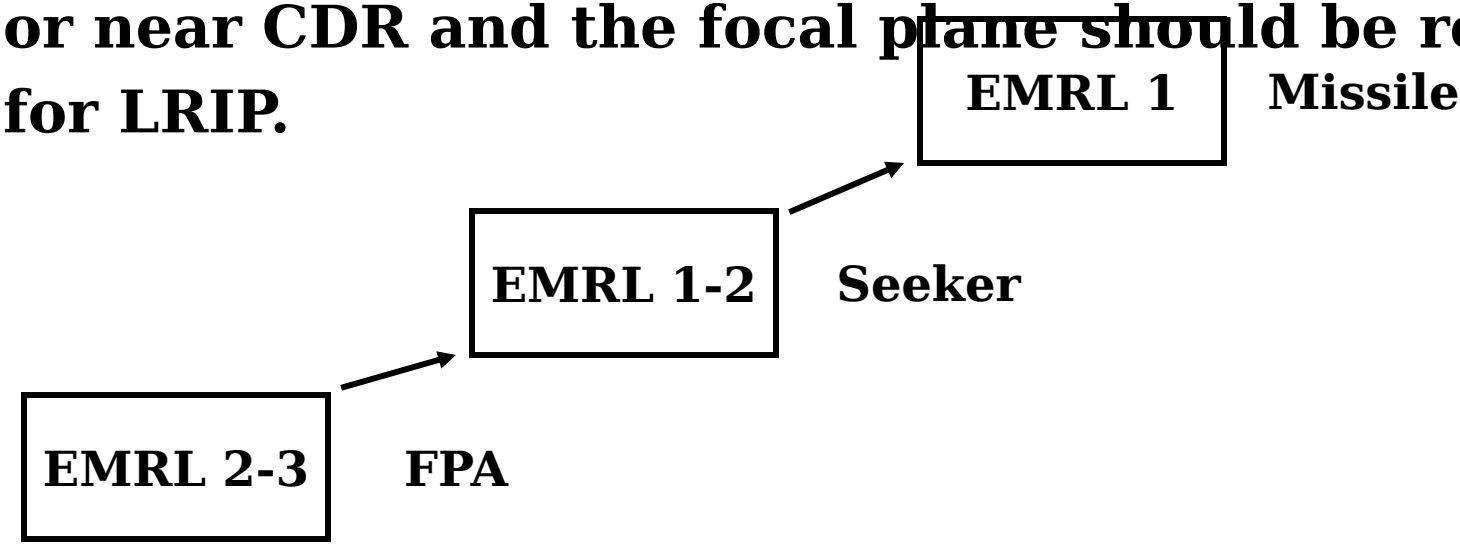
Metric Roll up chart



EMRLs and WBS

- **EMRLs can be tailored to apply at the item, component, subsystem and system levels**
- **Each lower WBS product should be at a higher level EMRL (level of readiness) than the higher level product, i.e., if the missile has met the exit criteria for Milestone B, the seeker should be at or near CDR and the focal plane should be ready for LRIP.**



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Backups

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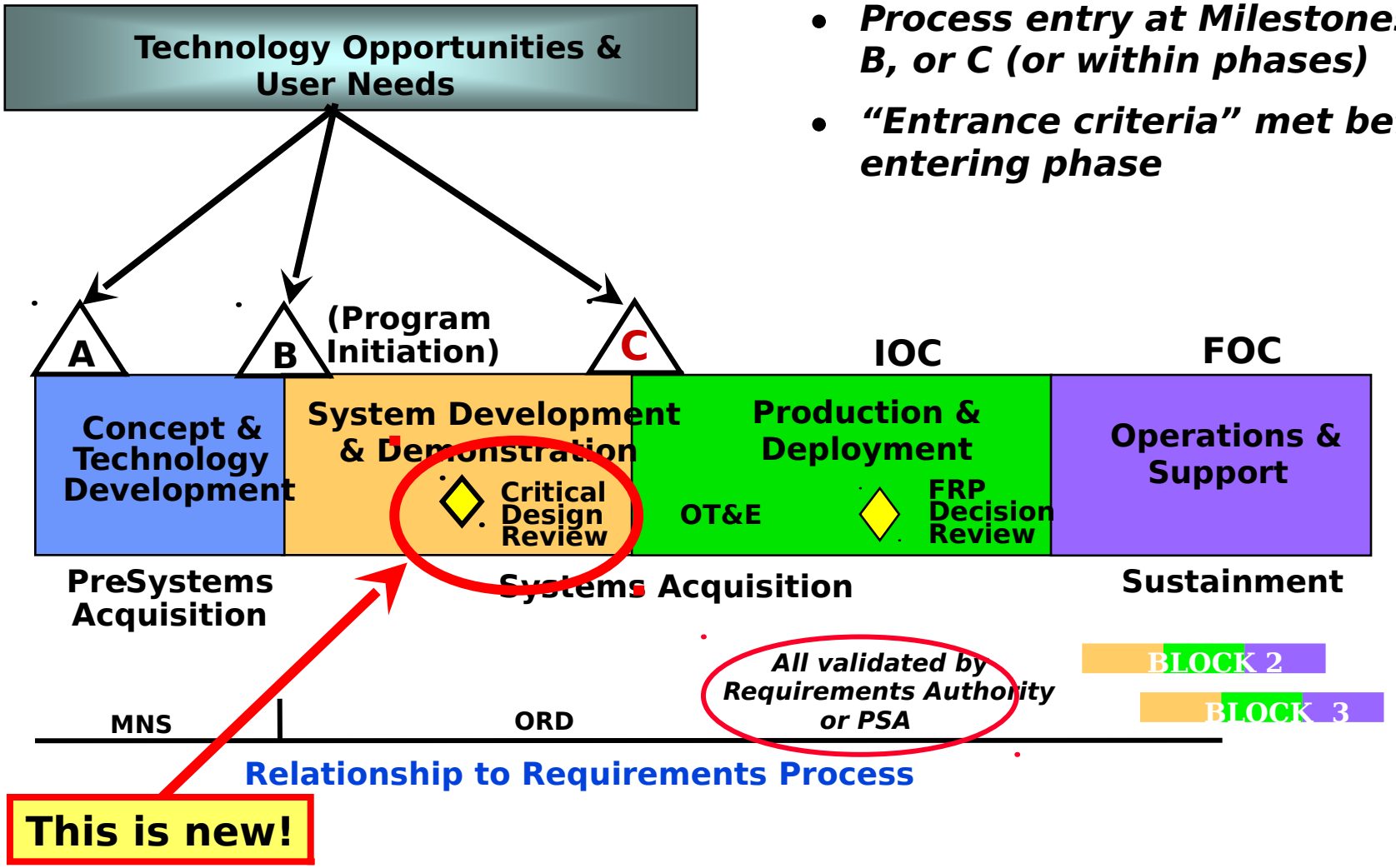
TRL Definitions

Technology Readiness Level	Description
1. Basic Principles observed and reported.	Lowest Level of Technology Readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there is no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3. Analytical and experimental critical functions and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in laboratory.
5. Component and/or breadboard validation in relevant environment.	Fetidity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond TRL 5, is tested in a relevant environment. Represents a major step up in technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment, or in a simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment, such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.
8. Actual system completed and "flight qualified" through test and	Technology has been proven to work in its final form and under expected conditions. In almost all cases, TRL represents the end of the true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it

THE 'Newer' 5000 Model



- ***Process entry at Milestones A, B, or C (or within phases)***
- ***"Entrance criteria" met before entering phase***